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SCIENTIFIC RESULTS OF PROCESSING OF PANORAMAS OBTAINED FROM PHOTOGRAPHS OF THE LUNAR SURFACE TAKEN FROM "LUNA-9"

by

A. I. Lebedinskiy

(USSR)

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by A. I. Lebedinskiy

On 3 Febuary 1966 the Soviet automatic station "LUNA-9" effected a soft landing on the lunar surface and transmitted to Earth with the aid of a television camera circular panoramas of the portion of lunar surface surrounding the station. This prominent scientific and technical achievement is the result of labor by a large association of scientists, engineers and workers of the Soviet Union.

The Academy of Sciences of the USSR edited a book entitled "First Panoramas of the Lunar Surface", in which the obtained photographs have been reproduced with a documented precision, the description of the experiment is given and the first results of the preliminary processing are brought out. These results are briefly expounded in the present report.

The automatic station "LUNA-9" transmitted three panoramas (I, II, III), obtained at respective heights of 7, 14 and 27° of the Sun above the lunar horizon, and also fragments of panorama during the additional session at Sun's height of 41°. The first panorama encompasses the entire horizon. Because of the station's inclination increase, the horizon to the West is not seen on the subsequent panoramas, and this is why the corresponding portion of it was not transmitted.

The variation of station's inclination (from 16.5° to 22.5°) took apparently place on account of lunar ground deformation under the effect of station's weight. As a result, a shift of the television camera was obtained, which permitted to define the distances to visible objects by using the stereoeffect. Inasmuch as the station is located near the Moon's equator (its selenocentrical latitude is 7°), the Sun rose nearly in the plane of the first vertical and the direction of shadows varied little. This is why the difference in the lengths of shadows did not practically interfere with the observation of the stereoeffect.

For the determination of the magnitude and the direction of the television camera displacement the determination of distances was applied with the aid of three dihedral mirrors. Six narrow portions of the panorama were reflected in the mirrors, for which stereopairs were formed by comparing directly the images obtained with those in the mirrors, and the distances were measured to the objects from the panorama center. Comparing the topographic planes of these narrow sectors on various panoramas, the shift of panorama center, that is, the foundation for the stereoscopic determination of distances, was determined. Then a topographic plan was constructed for the region of the sectors where the stereoeffect is notable, and also a topographic layout encompassing the greater part of the observed portion of the lunar surface.

The investigation of the relief of the portion of lunar surface surrounding the station was also conducted without the use of the stereoeffect. The fact of the matter is that when examining the panoramas, it is revealed that the station is located on the slope of a depression, possibly a lunar crater. The edge (rim) of this crater is well noticed on the photographs. Assuming that this rim is horizontal, it is possible to determine the shape of the crater independently, by each panorama, and it appears to be practically circular, with diameter near 15 m and a depth not greater than 1 m, probably 0.7 m.

The structure of the lunar surface is well visible on the panoramic photographs. Details of millimeter dimensions are distinguished near the station. This provides the possibility of studying the morphological and geological peculiarities of the place of landing. Amongst the details, visible on the panoramas, a series of characteristic types of formations are exposed, each of which is repeatedly reappearing. The identity of structure of details remote from one another excludes the possibility of considering the observed shapes as being created by random effects of illumination or by casual disposition of elements that are not interconnected; this, in particular, refers also to very tiny formations.

On the basis of the consideration of images, of morphological comparison of monotypic details in various regions of the panorama, and of comparison of panoramas, taken at different heights of the Sun above the horizon, it is possible to outline the following characteristic types of microsculptures, that is, of tiny details of surface structure.

1.–The lunes or craterlets appear as rounded-out hollows of small dimensions, as a rule not having any, or having a hardly noticeable rim. The coarser ones will be called craters, as is customary for the well known lunar formations.

2. - The linear structures of various types usually intersect one another in various directions, forming at times characteristic radial or forked (Y-shaped) formations.

3. - Stones.

There are numerous portions with complex structure that lend themselves to different interpretations.

Aside from the clearly expressed forms above, intermediate, mixed and other details, devoid of any characteristic shape, and having apparently emerged as a result of multiple actions by various processes of either endogenous or exogenous nature, are revealed on the panoramas. The latter emerge as a result of meteorite and stone impacts, and also of solar wind particle action.

The predominating type of relief in the portion studied is constituted by negative shapes, having the aspect of circular pits, craters, funnels, craterlets typical of the entire surface of the Moon.

The number of craterlets of various dimensions, registered on the topographic plane, is compiled in the table hereafter.

Diameter cm	Number of craterlets	Diameter cm	Number of craterlets
6 – 9	6	25 – 27	2
10 – 12	11	28 – 30	2
13 – 16	14	31 – 33	2
16 – 18	8	34 – 36	1
19 – 21	6	37 – 39	2
22 – 24	3	40 – 45	2

The minimum dimension of the observed craterlets is about 5 cm. It is comparable with the dimensions of the structural formations of the vesicular (honeycombed) lunar surface against the background of which the rounded shape of the craterlets is no longer perceptible, while the edges acquire ragged, irregular contours. It is possible that this is due to massive craterlet superimposition. Only in rare cases can rounded craterlets with diameter less than 5 cm. be distinguished.

Separate craterlets are encountered everywhere on the panorama, including the slopes of larger scale craterlets, and possibly also on the surface of a series of stones on which portions are shown that resemble a conchoidal fracture and a fine pitting of the surface. Craterlets of small dimensions are often assembled. In these cases they form ragged vesicular portions. Separate cells (honeycombs) within the group have usually edges of irregular shape, acquiring at times the character of a honeycomb structure.

Judging from shadows, the steepness of the inner slopes of craterlets with dimensions of more than one decimeter may, sometimes exceed 41°. In tinier craterlets, which merge with the cells, all possible inclinations are encountered, possibly including the negative angles of the inner soil voids.

On the plan, based upon the stereoscopic determinations of distances, we succeeded in measuring the depths of five craterlets of 10 - 20 cm dimensions, with the diameter of depth ratio from 6 to 4, and of one craterlet with 1.6 m in diameter, in which this ratio is about 10. At the same time, the inclination angle of the slope attains in one case up to 55°, provided we approximate the craterlet to a cone; this is because the craterlet in question lies on the steep wall of another, coarser formation. Profiles were constructed for seven craterlets by the variations of the position of shadow edges as the Sun rose over the horizon.

It may be seen by stereoscopic examination of the panorama, that in a part of craterlets and funnels the inner edges do not indicate either cup-like or conical shapes, but widen upward and suggest by their shape the "trumpet" of a phonograph loudspeaker. The ascertaining of the true nature of funnels with such a shape, also noted in the Ranger - 7 photographs, offers great interest. Such a type of funnel forms in particular in a ground explosion in the case of a sharp increase of strength with depth. At the level where the inclination of the funnel's slope varies abruptly, there takes place a substantial variation in strength properties of the ground. The depth of this level is different for various craters, but it is comprised within the range of a few centimeters.

The following remarks can be made relative to indivudual peculiarities of craterlets. No slide-produced loose material is usually noted in craterlets, possibly because not all of them are fully examined. However, some sort of separately fallen-in stones or clots may rather rarely be seen as well as accumulations of particles forming something resembling a central hill (ridge). The fine spongy structure of the illuminated part of the craterlet, situated within the resolution threshold of the television camera, is seen on the illuminated slopes of certain craterlets, and may be set against the coarsely cellular structure of other craterlets, particularly well noticeable in photographs, transformed to what thwy would be looking like at observation of the lunar surface from above. Thus, two varieties can be outlined at least in the microsculpture of the funnel's bottom. In many cases, the bottom of the funnel resembles in the microsculpture the surrounding rock.

A great interest in offered by the linear structures observed on photographs. They are noticeable on all the well examined portions of the lunar surface nearest to the station, but their particularly sharp expression is attained between the panoramic longitudes 140 - 150°.

The small width of the linear structures (usually centimeters) and the insignificant relief allow their perception only at specific illumination conditions. At low position of the Sun they are hardly noticeable, being covered up by the long shadows of the irregularly disposed surface irregularities. For a reliable tracing of these structures, a difficulty of different character arises from the natural tendency of the eye to assemble the disorderly scattered points into a system. Thus, despite the fact that the mere presence of linear structures calls for no doubts, their incorporation into any system is not always trustworthy, and is subjective to some extent only now and then.

For more reliable linear structures of lengths from 20 to 30 cm a vectorial diagram of directions has been constructed. It shows that two prevailing directions take place along the azimuth: $0-10^{\circ}$ and $40-50^{\circ}$.

Apparently linear formations are stronger than the surrounding rock, but they are disintegrating with comparatively greater ease into tiny structures in transverse direction. It is possible that these are outcrops of tiny veins as a result of superficial erosion; they have greater strength than the surrounding formations.

Seen in the panoramas are also formations of the stony type. The word "stone" is introduced as a conditional term. Being too indefinite, it is seldom used in the geological literature, where it is replaced by narrow conceptions characterizing the nature or the morphology of rock fragments. But this term is practical precisely on account of its indefiniteness when applied to the denomination of formations on the surface of the Moon resembling stones at least for their more accurate determination.

Seventy-five stones larger than 2 cm are brought up on the plan of the studied part of the Moon. Plotted on it were only those objects to which the distance was determined stereoscopically. According to direct counting by the panorama, the number of stones is about doubled. We may assume for an approximate calculation that there are no less than 150 stones of different dimensions over an area of about 50 m^2 visible on the panorama; this corresponds to an average quantity of about 3 stones of such a type per square meter of lunar surface. A surface of this kind may legitimately be denominated as a stony scattering.*

The size of each stone is characterized by a certain average magnitude. The distribution of the stones represented on the panorama by dimension is brought out hereafter.

Sizes, cm.	2—5	5—10	10—15	15—20	20—25
Number of stones	32	31	4	6	2

It should be taken into account that because of visibility conditions, the tinier material is lost on the more remote plans, while the true distribution curve must be characterized by a greater prevalence of stones of smaller sizes.

The surface of the stones often has a peculiar, unequal, "eaten" or corroded aspect, that suggests the eolian erosion or superficial dissolution of certain terrestrial rocks. An irregularity of either the acting agent or of the formation's stability is usually clearly outlined in these processes.

*cf. alluvial or eluvial deposit in geology.

Speaking of the character of occurrence of the stones, it should be recalled that some of them convey the impression of stones either freely lying on the surface or having rolled down the craterlet, while the others appear as if they outcropped in the process of ground disintegration. It is possible that the row of stones at 190^{o} longitude is the result of erosion.

Certain stones are raised, finding themselves on some peculiar pedestal. The rise of the coarse stone at 25^{o} longitude is clearly noticeable by the distortion of the shadow.This is probably explained by the fact that stones create a sort of a peculiar "protecting shadow" from the action of erosion factors, thus contributing to preservation of the ground beneath them.

On the whole, the picture observed near the station corresponds to a negative balance of mass, that is, to the gradual disappearance of the superficial layer's matter.

Within image resolution of a few millimeters, no traces of structureless dust or loose layer processes of superficial rock melting are found on the nearest plane.

The disintegration process is difficult to figure out without resorting to the process of dust-like thinly dispersed material formation. This is why one may think that the triturated matter forms specific structurally-bound aggregates, thus complicating the structure of the surface.

As a result of negative mass balance, the ancient rock structure manifests itself.

The temporal diversification in the formation of the various elements of the surface and the well known complexity of its geological history that can hardly amount to "one-time-one-type process" can already be seen by a mere consideration of a small portion of the Moon. Thus, a series of processes may be put forward to explain the creation of the contemporary surface of the Moon, of which the conjunction in terrestrial conditions is unknown.

Their analogy may have to be sought for in entirely different geologic formations, or else, these processes must be produced in laboratory conditions.

THE END

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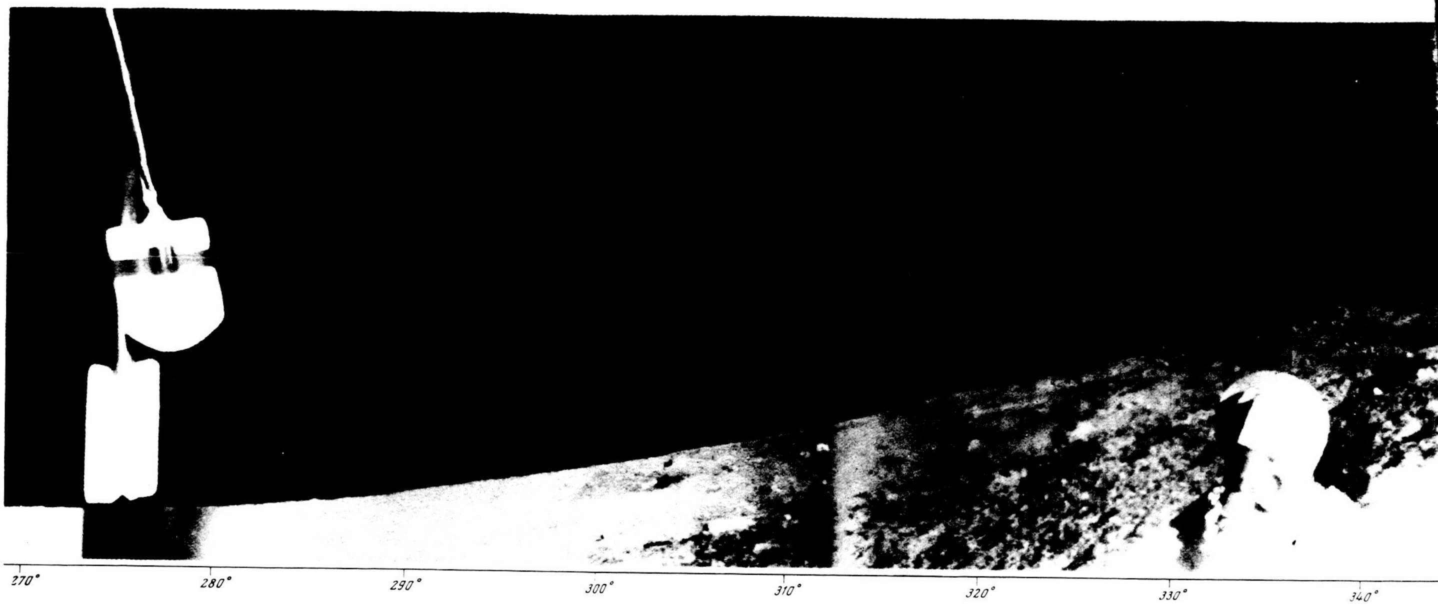

Панорама I

Панорама II

Панорама III

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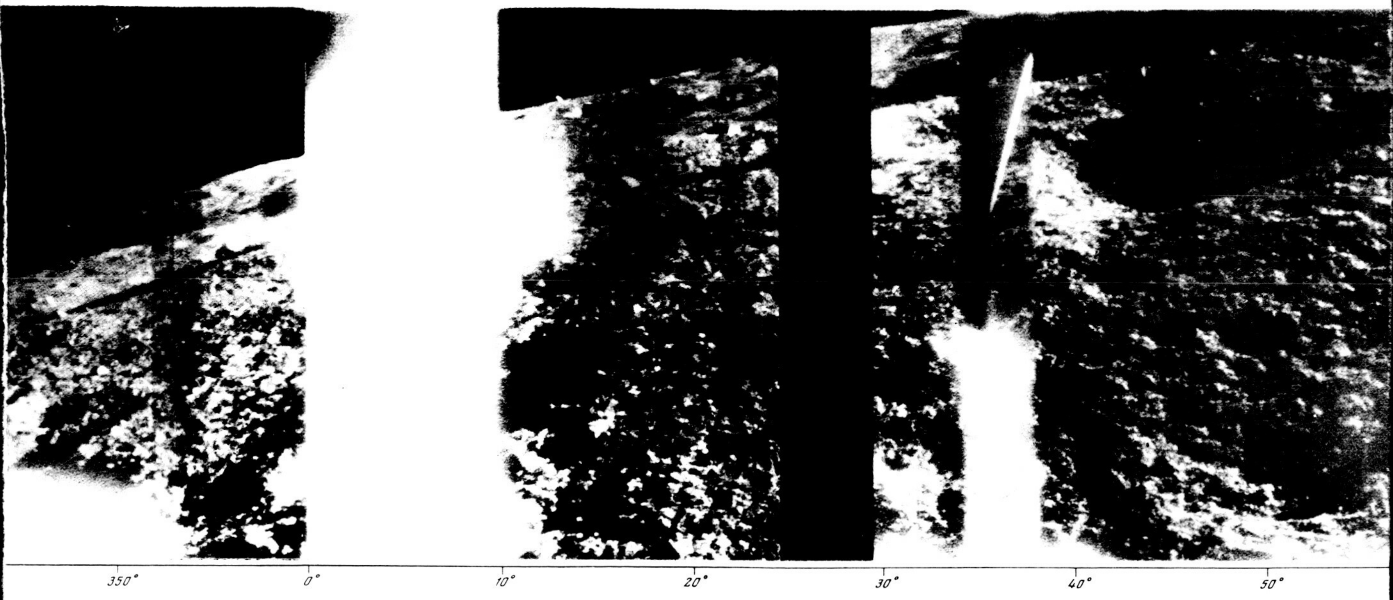
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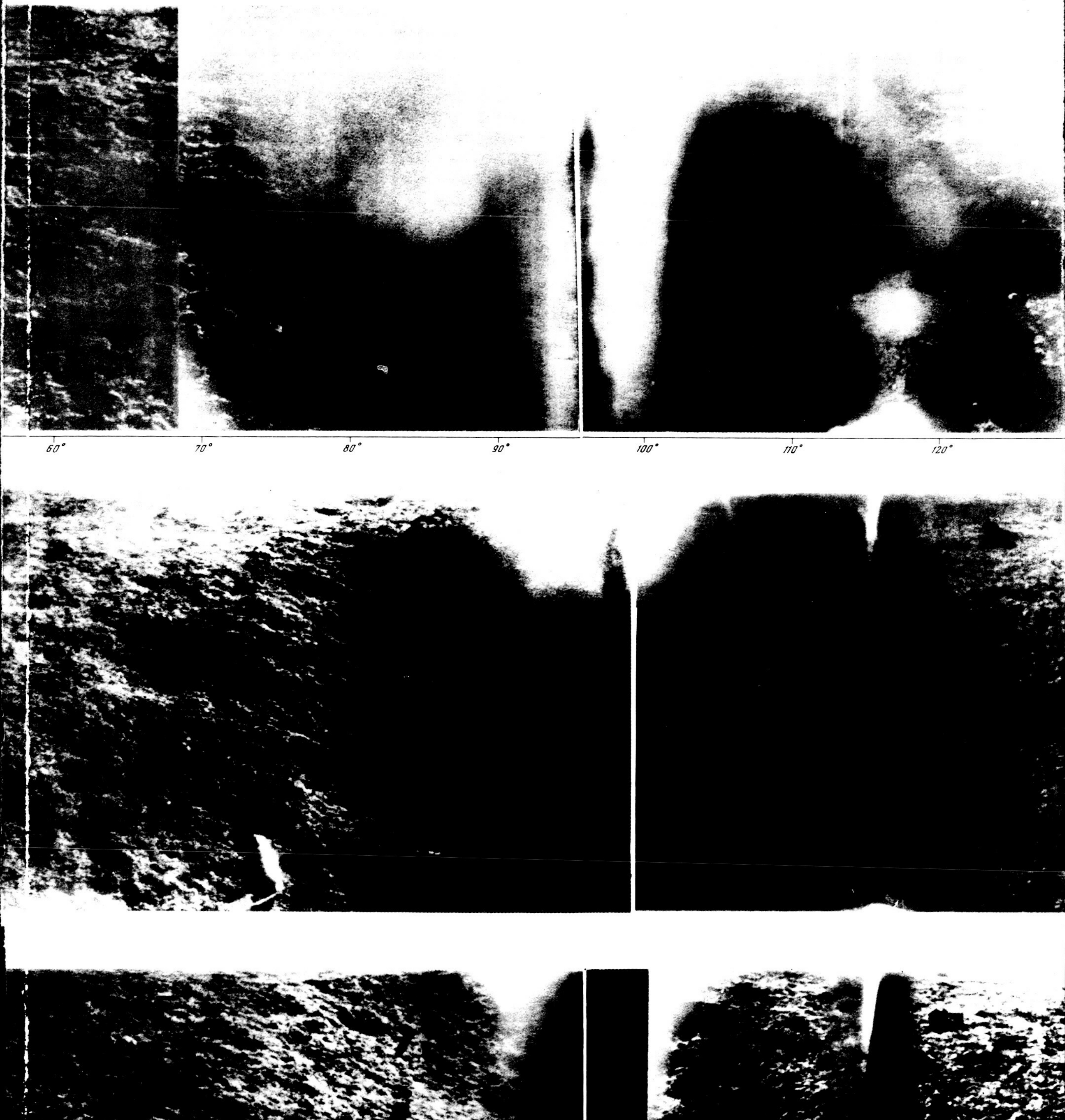

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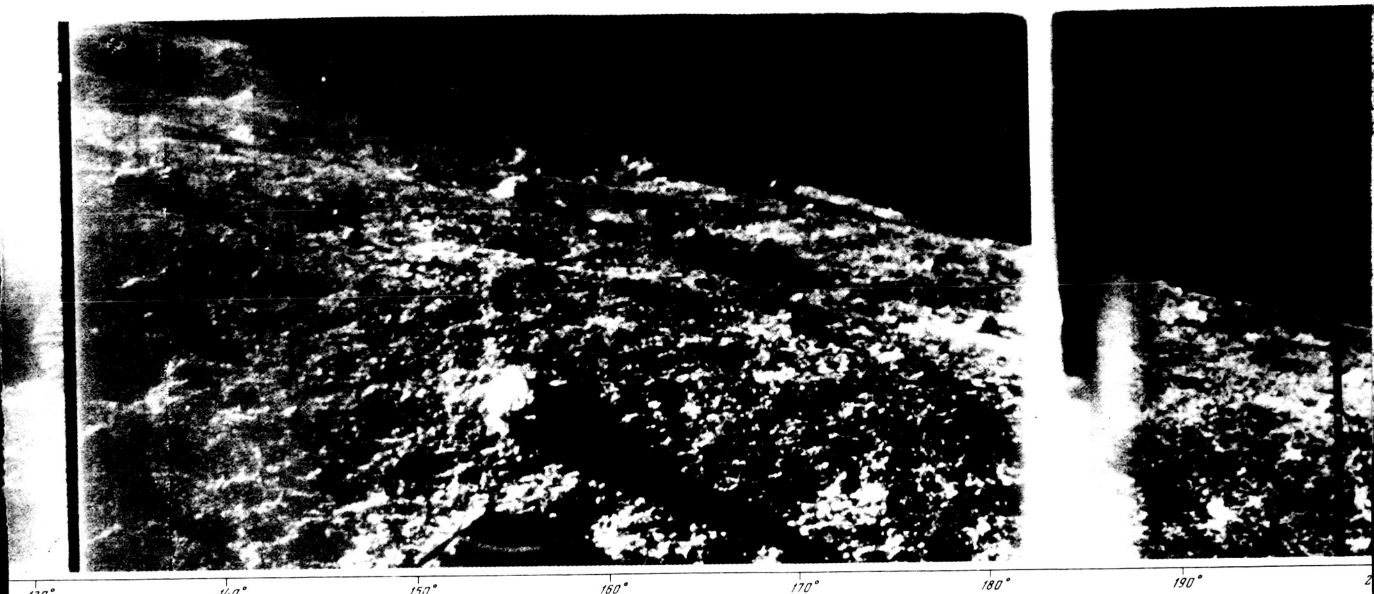
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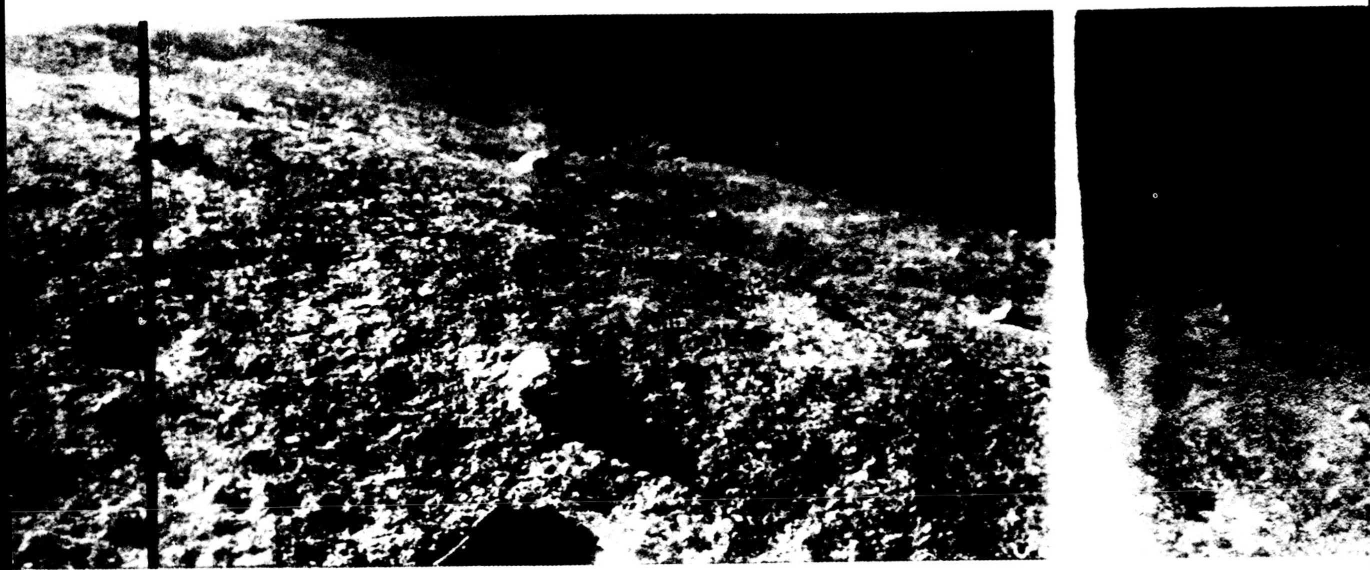

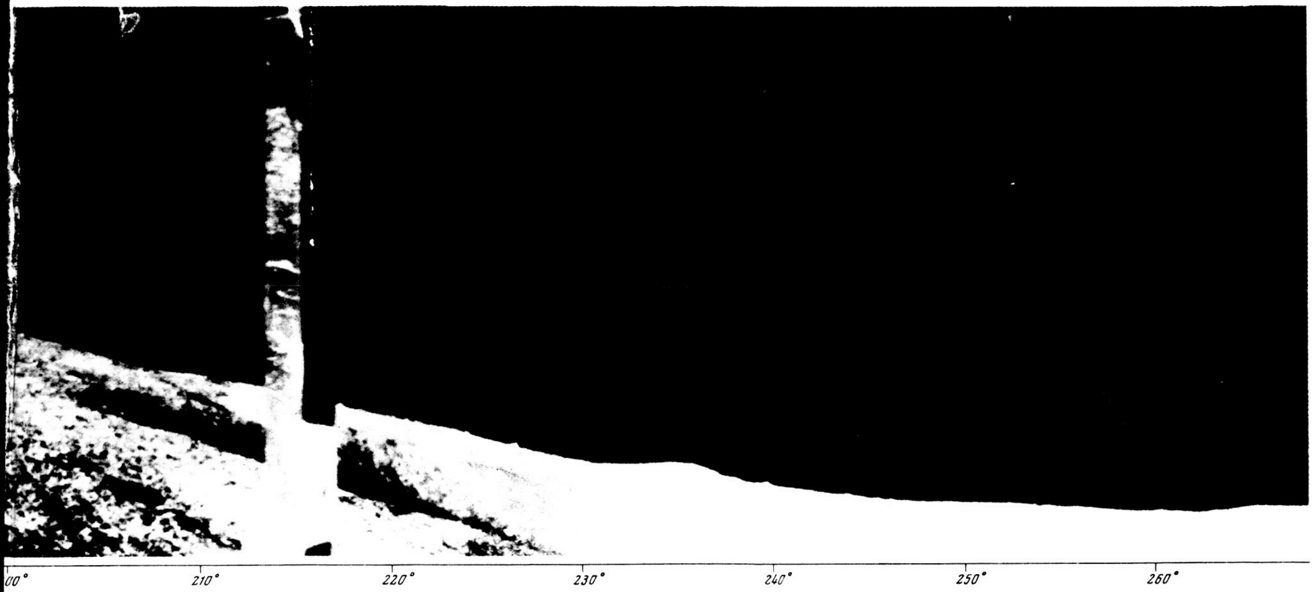

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